High Tibial Osteotomy: A Systematic Review and Current Concept

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Abstract

High tibia osteotomy is a common procedure in orthopedic surgery. A precise overview on indications, patients selection, pre-operative planning, surgical technique, methods of fixation, and complications have been presented. This paper focused on the points that should be considered to achieve good long-term outcomes.

Keywords: Genu varum, High tibial osteotomy, Open wedge, Upper tibial osteotomy

Introduction

High tibia osteotomy (HTO) is intended to transfer the mechanical axis from medial to slightly lateral to the midline of the knee to decrease the load and subsequently delay osteoarthritis (OA) (1-3). Some studies showed that regenerative process began after realignment (3-5). HTO was considered as an option to treat an isolated medial compartment OA in varus knees, which was reported by Jackson in 1958 (6). This surgery was not popular until Coventry reported good results in 1973 (2). HTO became more popular in young active patients after improvement in surgical technique, fixation devices, and patient selection with fewer complications (7-10).

Indications

There are some evidences that stretch the indications to ankle problems in patients who have pain and instability because of a varus ankle malalignment (11). Other indications in the presence of varus knee are meniscal transplantation after total medial meniscectomy, isolated chondral defect in the medial compartment of a varus knee, secondary degenerative arthritis in a varus knee with medial joint line pain, and ligamentous instability with varus thrust in which correction of the varus deformity unloads the reconstructed ligament while it heals (12-17).

History and Physical Examination

Observation of patient’s gait and stance especially to assess varus thrust and the presence of lateral collateral ligament insufficiency is of importance. Limb length discrepancy, ankle deformity, joint instability including insufficiency of collateral and cruciate ligaments should be considered for concomitant or staged surgery (18, 19).

Essential radiographs for the primary assessment starts with four views including anteroposterior (AP) and lateral views of the knee, axial view of the patellofemoral joint, and weight-bearing alignment view showing both lower extremities from hip to ankle. Stress views are mandatory when physical exam reveals ligamentous laxity (20). The tibia bone varus angle (TBVA) is measured on AP radiograph [Figure 1] and TBVA >5° is a good prognostic factor after osteotomy (8, 21, 22). Patella height is evaluated on the lateral radiograph using Insall-Salvati index (23).

Patient Selection and Prognosis

The highly accepted protocol was developed by ISAKOS (International Society of Arthroscopy, Knee Surgery and Orthopedic Sports Medicine) in 2004 (19). An ideal patient for HTO is a moderately active high-demand (but not jumping or running), young (between 40-60 years old) with isolated medial joint line tenderness, BMI <30, malalignment <15°, metaphyseal varus (i.e. TBVA>5°),
full range of motion (ROM), near-normal lateral and patellofemoral compartments, without ligamentous instability, non-smoker, and with some level of pain tolerance. HTO is contraindicated in patients older than 65, severe OA of the medial compartment (Ahlback grade III or higher), tricompartmental OA, patellofemoral OA, ROM<120° and flexion contracture >5°, diagnosed inflammatory arthritis, large area of exposed bone on tibial and femoral articular surface (> 15x15 mm), and heavy smokers (2, 24-32).

Good prognostic factors are preoperative TBVA>5°, postoperative obliquity of tibiofemoral joint line in a narrow range close to 0°, anatomical valgus alignment of ≥8° at five weeks post operation, age<50 years, excellent preoperative Knee Society score, and Ahlback grade 0 arthritis of medial plateau (33-36). Negative prognostic factors are obesity especially more than 1.3 times of the normal population weight, nicotine users, valgus alignment of ≤5° at five weeks post operation, postoperative flexion<120°, and age>56 years old (34, 36).

Niemeyer et al published a minimum of 36-month follow-up of 69 patients after medial open wedge high tibial osteotomy (MOWHTO). They concluded that the severity of medial plateal cartilage defect did not affect the clinical results of surgery, and partial thickness defect in lateral tibial plateau was well-tolerated (8).

**Pre-operative Planning**

Mechanical axis (line from the center of the femoral head to the center of the knee), anatomical axis (a line from the piriformis fossa to the center of the knee joint and a line through the long axis of the tibia), and weight bearing axis (line drawn from the center of the femoral head to the center of ankle joint) are measured on the alignment view, where the location, type, and amount of corrective osteotomy is determined. Normally 60% of the body weight force passes through the medial compartment (37). Normal values include a mechanical axis of 1-3° varus, anatomical axis of 5-7° valgus, 6° of valgus between the mechanical and anatomical axes, and the weight bearing line passing through the lateral 30-40 % of the tibial plateau (37-40). Unicompartmental OA usually becomes symptomatic when the alignment is more than 10° off of the normal range (41).

The goal of valgus HTO is to reach a slight valgus axis to prevent recurring of varus. Nearly 8-10° of valgus in the anatomical axis or 3-5° of valgus in the mechanical axis are considered optimal correction after surgery (28, 42-47). Slight varus correction can lead to recurrence of deformity whereas overcorrection can cause lateral compartment OA (28, 42).

In our practice, we use a simple approach to determine the angle of correction that originally goes back to the research of Fujisawa et al and later adapted as a guideline to determine pre and postoperative amount of varus correction (40, 48). The weight bearing line (WBL) should pass from 62% of the tibial plateau width when measured from the medial tibial plateau. [Figure 2]. This point – called Fujisawa point – matches over the mechanical axis with 3-5° valgus and locates slightly lateral to the lateral tibial spine. To determine the amount of required correction, a line is drawn from this point to the center of the femoral head and another to the center of the ankle joint. The angle created by
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Surgical Technique

It is recommended to start the surgery with knee arthroscopy to debride the lateral compartment and manage the concomitant pathologies (50). Medial opening wedge, lateral closing wedge, and dome osteotomy are comparable techniques in the correction of genuvalgum.

Lateral closing wedge osteotomy

Lateral closing wedge osteotomy is the historic approach and is more familiar to some surgeons. The advantages are greater potential of correction, no need for bone grafting, and faster healing (27, 34, 42, 43, 51-53). Disadvantages are concomitant fibular osteotomy or release of the proximal tibiofibular joint, risk of peroneal nerve injury (occurs in 3.3-11.9%), the need for two bone cuts, ability of malalignment correction in only one plane (frontal), shortening of the leg, loss of bone stock, and more difficult conversion to arthroplasty with muscle detachment (7, 44, 54-58).

An anterolateral L-shaped incision is made starting 1 cm below the joint line that continues toward the anterolateral edge of the tibial tubercle and anterior tibial crest. The anterior compartment fascia is cut close to the anterior tibial crest and anterior tibialis muscle is elevated using a periosteal elevator to expose the bone. Osteotomy starts above the tibial tubercle preferably 15 mm below the joint line (59-66). Shorter distance from the joint line may cause ancillary fracture or avascular necrosis of the tibial plateau. Osteotomy is directed medially parallel to the joint line. Medial cortex and periosteum is preserved to act as a hinge while closing the osteotomy. It is highly recommended to remove a wedge 2-3 mm smaller than preoperative planning to avoid overcorrection by overlapping the proximal and distal bone segments (49).

Medial opening wedge osteotomy

Medial opening wedge osteotomy has been more popular recently. The advantages are the ability to correct the alignment in two planes (coronal and sagittal), no need for fibular osteotomy, little risk of peroneal nerve injury, no limb shortening, use of a single cut with no need to detach the muscles, no bone loss, easier conversion to arthroplasty, and ability to adjust the amount of correction during surgery. Disadvantages are the need for bone graft, and the risk of delayed union or nonunion (7, 19, 34, 51-54, 66). MCL becomes slightly tight after MOWHTO. Moreover, surgeon should be cautious about increasing in posterior tibial slope (PTS), patella height (PH) and patellofemoral compartment pressure that often occur when too much correction is done (67, 68). McNamara et al suggested a concomitant tibial tuberosity osteotomy if more than 12.5 mm correction is required to avoid adverse effects of patella infra and increased

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Table 1. Studies reporting the results of the Spacer plate and Tomofix plate

<table>
<thead>
<tr>
<th>Study</th>
<th>Published</th>
<th>Implant</th>
<th>Failure rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lobenhoffer and Agneskirchner (7)</td>
<td>KSSTA, 2003</td>
<td>Spacer plate</td>
<td>6% in 101 patients</td>
</tr>
<tr>
<td>Spahn et al (80)</td>
<td>Arch Orthop Trauma Surg, 2004</td>
<td>Angle stable implant and spacer plate</td>
<td>No failure in angle stable implant, 11.7% failure in spacer plates</td>
</tr>
<tr>
<td>Staubli et al (9)</td>
<td>Injury, 2003</td>
<td>TomoFix</td>
<td>2% failure in 92 patients</td>
</tr>
<tr>
<td>Lobenhoffer, Agneskirchner and Zoch (88)</td>
<td>Orthopade, 2004</td>
<td>TomoFix</td>
<td>No failure in 262 patients, 2 patients needed required bone grafting</td>
</tr>
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patellofemoral compartment pressure (69).

An incision is made in the mid-course between the posterior-medial border of the tibial tuberosity. Sartorius and vastus lateralis are retracted medially to expose the joint capsule. It is necessary to peel off the MCL from its insertion to unload the medial compartment after osteotomy (70).

Han et al studied on 18 fresh frozen human cadaver knees and found a safe zone to avoid breaking the lateral cortex (71). This safe zone is an area between the tip of the fibular head and the remnant of fibular head epiphysis line [Figure 3]. Two K-wires are placed 4 cm below the medial joint line toward the safe zone of the lateral cortex under fluoroscopy and osteotomy is done below and parallel to the k-wires using an oscillating saw leaving the lateral 10 mm intact. Care must be taken to preserve this hinge in the lateral cortex while the two thirds of the medial and posteriormedial cortex is cut. Thin osteotomes are used to gradually open the osteotomy and finally a calibrated osteotome is used to achieve the desired correction.

To keep PTS and PH within the normal range, the authors follow the recommendations of Hernigou et al and Noyes et al (72, 73). A study by Asada et al showed that excess increase in the PTS resulted in loss of correction in the coronal plane and failure of surgery (74).

Many surgeons prefer to fill the osteotomy gap with either autograft or allograft, such as smokers and obese patients (93). Results with autograft were much better with lower complications in comparison with allograft and bone substitutes such as calcium-phosphate ceramic spacer (94). Staubli et al studied the bone healing using radiography after HTO without filling the osteotomy gap. They showed that healing starts from the lateral hinge and gradually progresses toward medial (90). Callus formation and ossification is visible three months after surgery. The new bone fills 75% of the gap 6 months after surgery. Almost 90% of the patients achieve full consolidation on radiography, CT scan, and MRI in one year.

Spacer plates (i.e. the Puddu plate and Aescula plate) are small, low profile implants that require small incision with less soft tissue damage. However, these plates are less rigid with the possibility of delayed union, nonunion, and failure of fixation leading to increased posterior tibial slope (7, 74, 80, 81), which necessitates longer period of non-weight bearing for at least 6 weeks after surgery (19, 82) [Table 1].

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In terms of fixation with plate fixators patients undergoing MOWHTO using TomoFix plate were much better with lower complications in comparison with allograft and bone substitutes such as calcium-phosphate ceramic spacer (94). Staubli et al studied the bone healing using radiography after HTO without filling the osteotomy gap. They showed that healing starts from the lateral hinge and gradually progresses toward medial (90). Callus formation and ossification is visible three months after surgery. The new bone fills 75% of the gap 6 months after surgery. Almost 90% of the patients achieve full consolidation on radiography, CT scan, and MRI in one year.

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Methods of fixation

Plate fixation

Spacer plates (i.e. TomoFix plate) are based on the locking compression plate (LCP) concept offering the advantage of a rigid fixation, possibility of early weight bearing after two weeks, and early start of motion while the normal preoperative PTS is maintained (8, 19, 74, 83, 84). Eight locking bolts are the minimum required number of screws for a rigid fixation with four proximal and four distal to the osteotomy site. At first, the proximal bone segment should be fixed and a lag screw is then inserted in the first distal hole below the osteotomy to increase stability by applying compression on the lateral hinge of the osteotomy. unicortical screws are inserted in the three remaining bolts.

Agneskirchner et al studied the biomechanics of 3 spacer plates with different length, two with locking bolts, and one was the TomoFix fixator (85). The TomoFix plates were superior at single load-to-failure and cyclic load-to-failure tests and had the maximum residual stability after failure of the lateral cortex. Also motion at the osteotomy gap was the least with the TomoFix plate. Other studies have shown that the TomoFix plate was superior over the spacer plates in achieving rigid fixation and allowing early weight bearing (86-88).

Kachooei et al reported good short term outcome for MOWHTO with Orthopedic Dual Sliding Compression Plate (ODSCP) using 2 to 3 non-locking screws on each side (89). The plate is inserted before correcting the alignment to hold the bone fragments in place. This removes the potential risk of unwanted translation or rotation of the bone, which used to be a complication of the traditional procedures. Further, if the angle of the limb alignment needs to be re-adjusted after surgery, this plate enables this without the need to remove the bone screws because of the double sliding plates. Inserting the bone screws takes place before the correction force is applied with the screws locating beneath the plateau, thereby reducing the chance of extension of the osteotomy into the joint.

Bone healing after HTO

Staubli et al studied the bone healing using radiography after HTO without filling the osteotomy gap. They showed that healing starts from the lateral hinge and gradually progresses toward medial (90). Callus formation and ossification is visible three months after surgery. The new bone fills 75% of the gap 6 months after surgery. Almost 90% of the patients achieve full consolidation on radiography, CT scan, and MRI in one year.

Spacers for MOWHTO

Many surgeons prefer to fill the osteotomy gap with grafts or bone substitute to enhance stability and accelerate the healing. Onodera et al studied on 38 patients undergoing MOWHTO using locking plate fixation and ceramic spacers (91). They found that post operative alignment and clinical outcome were comparable between hydroxyapatite (HAp) and betricalcium phosphate (TCP), but TCP was significantly superior for osteoconductivity and bioabsorbability after 18 months. Gaasbeek et al evaluated the site of osteotomy during plate removal after MOWHTO using TomoFix fixation and TCP filler (92). They observed that TCP was absorbed and the new bone was completely remodeled and incorporated into the native bone.

Autograft

Autogenous iliac bone graft should be considered as a good option in patients who are at risk of nonunion such as smokers and obese patients (93). Results with autograft were much better with lower complications in comparison with allograft and bone substitutes such as the calcium-phosphate ceramic spacer (94).

Postoperative rehabilitation

The protocol mainly depends on the rigidity of the fixation. In terms of fixation with plate fixators patients are allowed to start partial weight bearing (15-20 kg) immediately after surgery depending on the amount...
of pain and wound healing while full weight bearing is allowed after two weeks. Luites et al mentioned that there was no difference in weight bearing protocol between open and closed wedge HTO when fixed with the TomoFix plates (95). Since spacer plates are less stable, partial weight bearing is allowed at least 6 weeks after surgery.

**Survival rate of HTO**

Good long term results are closely related to correct patient selection, surgical technique, rigid fixation, and postop protocol. Ten-year survival rates for closed wedge osteotomy were reported from 51% by Naudie et al to 93.2% by Koshino et al (25, 34, 51, 59). The best results by Koshino was related to some post operation factors including no flexion contracture, valgus anatomical angle of 10°, and concomitant patellofemoral decompression procedure if indicated (96). Coventry et al also reported a 10 year delay in total knee arthroplasty in 75% of patients if overcorrection to at least 8° of valgus was achieved (34). Studies on MOWHTO showed a 10-year delay in arthroplasty in 63% of 73 patients (97), and 85% of 203 patients (97, 98). Longer delay in arthroplasty can be achieved if patients are selected based on TBVA (21,22).

Schallberger et al followed 54 patients with isolated medial compartment OA for a median of 16.5 years that were treated by either MOWHTO or lateral closing wedge osteotomy, and found 24% conversion to total knee arthroplasty. Moreover, there was no significant difference in score outcome and survival between open medial and closed lateral high tibia osteotomy (99).

In a randomized controlled trial on 92 patients after 6 years follow up, Duivenvoorden et al did not find any difference between MOWHTO and lateral closing wedge in terms of clinical outcome or radiographic alignment, in patients who did not end up to joint replacement. Authors showed that the MOWHTO was related to higher incidence of complications whereas the lateral closing wedge osteotomy was related to higher number of conversion to total joint replacement (100). Generally the results of high tibia osteotomy are good within the first ten years and deteriorate after 15 years (101, 102).

**Complications**

MOWHTO became more popular because of more favorable outcomes (103). Complication was reported from 8% to 55% after MOWHTO (81, 104-106). Lateral cortex breakage is considered an important risk factor for failure of fixation, which might result to at least 4° of loss of correction between immediate and final postoperative radiographs (94). Giuseffi et al evaluated 100 consecutive MOWHTO with a follow up of 4 years where they found that allograft combined with plasma rich platelets and/or DBM increased the risk of nonunion (107). Martin et al classified complications into three groups based on the patient reported outcome and requiring a treatment. Patients in groups 1 (no additional treatment) and 2 (conservative treatment) comprised more than 90% of patients. Only patients in group 3 required additional surgery or long term medical treatment for aseptic nonunion, deep infection, CRPS type 2, and severe hardware failure with loss of correction. Rate of additional surgery was about 3%. Severe adverse events were more common in patients with diabetes, active smoking, displaced lateral hinge fractures, and patients with no compliance (108).

High tibia osteotomy is a viable solution to address lower limb malalignment with concomitant OA, meniscal deficiency, focal chondral defects, and/or ligamentous instability. A comprehensive history and physical examination, precise patient selection and preoperative planning, using the appropriate fixation technique and rehabilitation protocol could help to achieve good long-term outcome.

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